An Ontology based Game Platform for Mild Cognitive Impairment Rehabilitation

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Keywords: Serious Games, Elderly, Mild Cognitive Impairment, Ontology, Knowledge Engineering, Rehabilitation, Usability Study.

Abstract: In this paper a new ontology based game platform for maintaining and recovering cognitive functions in the case of mild cognitive impairment is discussed. Leveraging on a knowledge base that specifies game rules and organizes training resources such as words, images and sounds in terms of categories, relationships and properties, a system is developed for the efficient creation of new exercises. The ontology model by organizing the material required in the patient rehabilitation process, reduces the workload of domain experts in terms of developing the practices to be applied for a subject. Employing an ontology, the main requirement is to create a model for each exercise type, whereas the platform will be responsible to synthesize the exercises by instantiating the models with the suitable resource objects automatically. In addition, the system can use the ontology to create and manage exercises by selecting the appropriate level of difficulty based on the patient's previous performance, skills and preferences. The design of the ontology and the architecture of the overall game platform are presented while experiences from a pilot evaluation study assessing the perceived usability of the game platform by elderly users are reported.

1 INTRODUCTION

Mild cognitive impairment (MCI) is a state of a cognitive performance below of what is expected for an age and an educational level, but above a pathological level (APA, 2011). MCI is one of the early symptoms of Alzheimer’s disease characterized by significant memory impairment that does not, however, meet the criteria for dementia (Sperling et al., 2011). MCI patients may forget important information previously recalled, such as meetings, conversations, or recent events but continue to exhibit normal functional activities. MCI is also linked to the impairment of other aspects of cognitive function, such as attention, language, visual or executive function, including the inability of a person to make the right decisions, judge the time or sequence of steps required to fully execute a complex task (Langa and Levine, 2014).

Long-term studies show that on a global scale 15-20% of people aged 65 and over may develop MCI (Hu et al., 2017). Besides ageing, a wide spectrum of diseases and clinical conditions are related to MCI. A review of 41 cohort studies with a maximum ten-year follow-up showed that, on average, 32% of people with MCI will develop dementia (Mitchell and Shiri-Feshki, 2009). In the case of cardiovascular diseases (stroke, heart attack, etc.), in addition to motor deficiency, patients develop cognitive and affective disorders (Abete et al., 2014). The relation of MCI to Parkinson's disease has been similarly examined (Janvin et al., 2006). Aphasia, a non-amnestic single cognitive domain MCI, does not affect memory and patients still reason as normal but are unable to communicate their thoughts (Seniów et al., 2009).

Given the increase of the proportion of older people in the world population as well as the sharp increase in the survival rate of patients with accute diseases which, however, affect their cognitive functions, the importance of developing MCI prevention and rehabilitation tools is obvious. In recent years the interest in cognitive rehabiliation has led to the discovery of pathogenetic mechanisms of cognitive impairment and the development of new approaches to the recovery of neurons of the brain (Carelli et al., 2017).

MCI causes cognitive changes that are severe enough to be perceived by the ailing individuals or their relatives. However, the neurological symptoms complexity makes it difficult to choose appropriate

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rehabilitation tools and requires a multidisciplinary approach to address them. Traditionally, the most common approach to support MCI rehabilitation is to give patients written exercises that they have to work out of - almost as with school work. This on the one hand makes it quite difficult for the specialist to keep records of each patient individually and on the other hand, it makes the procedure quite tedious for the patients, who receive similar exercises, causing their displeasure their reluctance to continue the process.

To this end, neuropsychologists are now increasingly using information and communication technologies, including serious games (Rodríguez-Fórtiz et al., 2016). Digital applications can provide a great alternative with respect to traditional methods, as they allow the patient to practice cognitive functions with rich media, such as sounds and images. A rehabiliation tool capable of managing such types of training material can generate different and operative experiences supporting the recovery process of the patient, while also recommending novel exercises that are difficult to realize with hard copy approaches.

In this paper a new ontology based game platform for MCI recovery is presented. Leveraging on a knowledge base that specifies game rules and organizes training resources such as words, images and sounds in terms of categories, relationships and properties allows for the automatic creation of new exercises. By organizing the material required in the patient rehabilitation process, the ontology model reduces the workload of domain experts in terms of developing the exercises to be applied for a subject. Employing an ontology, the main requirement is to create a model for each exercise type, whereas the platform will be responsible to synthesize the exercises by instantiating the models with the suitable resource objects automatically. In addition, via the ontology the system can adapt exercises by selecting the appropriate difficulty level based on the patient's previous performance, skills and preferences.

The rest of the paper is organized as follows. Section 2 presents related work. Section 3 discusses the game platform and ontology design and the details of system development. Section 4 presents evaluation in terms of assessing system usability and presents future work. Finally, our conclusions are given.

2 RELATED WORK

Experimental results show that cognitive as well as physical exercise help develop new brain neurons, which reduce the impact of dementia (Carelli et al., 2017). Research has shown that brain training should target specific brain activities (Tong et al., 2017). Specifically these activities are short-term (new information) and long-term (information retention) memory, switching between different tasks, word or object recognition and finally chronological and spatial placement.

In recent years, several serious games have been proposed focusing on various stages of cognitive damage (McCallum and Boletsis, 2013; Rodríguez-Fórtiz et al., 2016). The main purpose of these games is to delay the onset of symptoms of the disease. The use of these games can also lead to improved quality of life for patients, as it helps them to maintain their autonomy and social relationships. Although MCI is characterized as a cognitive dysfunction, support for both physical and social activities through games has been shown to contribute to delayed cognitive impairment and / or recovery, especially when combined with cognitive activities (Karp et al., 2006; Chartomatsidis and Goumopoulos, 2019).

A game suite, called Tapbrain, was developed for smart mobile devices (Kang et al., 2016). The game tool includes 17 mini-games, 13 to stimulate brain activity and 4 games to induce physical activity. Games are divided into six categories: four targeting brain exercise and two targeting physical activity. The games that stimulate brain exercise are divided in the following cognitive areas: memory, attention, problem solving and decision making. All the games have 5 levels of difficulty, while the first level operates as the educational level.

A similar tool developed for cognitive rehabilitation in tablet devices is Padua Rehabilitation (Cardullo et al., 2015). It consists of 35 exercises divided into 7 cognitive areas: attention, memory, language, logic, identification, orientation and motor control. The shapes of the objects used in the application are the basic geometric shapes avoiding complicated images and vivid colors. In order to minimize mistakes, each exercise starts from a very easy level and with the increase of playing the degree of difficulty increases. In this way, participants can easily finish the first level by gaining confidence and a positive attitude to continue using the application.

Garcia-Betances et al. (2015) presented effective strategies with virtual reality applications and their use in cognitive rehabilitation or in the daily life of people with MCI or dementia. They presented a detailed overview of strategies in cognitive rehabilitation and proposed methodologies and development phases either from a psychologist or an application developer perspective in order to achieve the maximum rehabilitation results.

Quaglini et al. (2009) suggested the use of a database and a graphical user interface to support the creation of new games and their objects with a focus on customizing them to the user needs as cognitive exercises. A follow up study by Leonardi et al. (2011) proposed that such games can be automatically created using an ontology, which models the games and their objects. A software tool that creates games and their corresponding objects which are specified in an ontology and are targeted to patients afflicted by Parkinson's disease was presented by Alloni et al. (2015). The ontology, however, in this case encodes only relationships between the game objects and does not support modeling of game rules or inference operations at the runtime (porting of the ontology to OWL specification is suggested as a future work).

The proposed approach shares similar goals with the related work and embraces the perspective of developing personalized serious games for the rehabilitation of impaired cognitive functions. It follows, however, a different approach by modelling not only the static relationships of game resources but also game rules that help to combine the knowledge of the ontology with the corresponding dynamic knowledge contained in these rules. Therefore, personalized game activities can be defined via rules according to user conditions and preferences. Finally, the platform functionality is accessible through HTTP protocol for client applications that can start at any place (home, care center) and on any device.

3 THE COGNIPLAT PLATFORM

3.1 General Objectives

The COGNIPLAT platform is an innovative cognitive impairment rehabilitation tool that is developed for assisting elderly who have MCI but have not yet developed dementia. It is built based on a multi-disciplinary approach combining theories of neuropsychology, cognitive linguistics and speech therapy organized in six domains, one diagnostic and five training domains focused on enhancing cognitive functions through different game exercises. In addition, the platform has been designed to automatically adjust the complexity and type of exercises by adapting the cognitive requirements of the games to the characteristics of each patient.

The *diagnostic domain* aims to evaluate, through a specific set of exercises, the degree of impairment of the patient's cognitive functions in order to determine the difficulty level of the exercises to start.

The remaining areas focus on the reinforcement of different cognitive functions through exercises. The *first cognitive domain* is focusing on memory and includes exercises that focus on recalling the position of objects and patterns, a sequence of numbers, elements of associative knowledge etc. The *second cognitive domain* focuses on attention with the use of exercises that request, for example, to replace words or phrases with images or image sequences and identifying objects displayed on the screen. The *third cognitive domain* focuses on enhancing the perception ability with the use of exercises that require some kind of orientation or determining the location of an object with respect to another. The *fourth cognitive domain* focuses on reasoning and problem solving with exercises such as solving arithmetic crosswords and selecting the right pattern to reasonably complete a given sequence. The *fifth cognitive domain* (not currently available) is focusing on utterance and includes exercises that concentrate on the mobilization of organs supporting utterance (i.e. lips, tongue, cheeks and jaw).

An innovation of the proposed platform is the use of the *propositional-frame method*, which aims at restoring the impaired relational cognitive connections that help a person navigate the surrounding world. The basis of this method is the assertion made by cognitive linguistics that one person thinks reasonably, associating one phenomenon with another. An effective tool in this regard is the use of derivative words that constitute the majority of vocabulary in any language. Derivative words are constructed by analogy from a verbal basis, and it is this property that facilitates their preservation in a person's memory. The use of an ontology that semantically describes this word formation process is foreseen in the COGNIPLAT platform to restore speech in older adults with MCI.

3.2 MCI Rehab Games

Currently the following games have been realized (the targeted cognitive domain is also indicated):

1. *Anagram*: solving a word puzzle (**reasoning**)
2. *Antonyms&Synonyms*: finding word antonyms/synonyms (**memory**)
3. *Calculation*: solving arithmetic crosswords (**reasoning**)
4. *ChronologicalOrder*: placing shuffled images in chronological order in order to create a brief story (**reasoning**).
5. *FindThePattern*: remembering a pattern of highlighted boxes appeared shortly in the context

of a background screen of several square boxes (**visual memory**).

6. *FindTheSound*: listening to sounds and selecting the corresponding image (**acoustic memory**).
7. *Labyrinth*: finding the exit from a labyrinth (**perception**).
8. *LogicalOrder*: selecting the right pattern to reasonably complete the given sequence (**reasoning**).
9. *MemoryCards*: revealing pairs of alike pictures (**memory**).
10. *NumberOrder*: ordering a random sequence of numbers in increasing sequence (**reasoning**).
11. *Observation*: counting specific types of objects given a set of discrete images shown on the screen (**attention**).
12. *Outsider*: finding an object that does not match with the rest (**attention**).
13. *Puzzle*: solving a photo puzzle (**attention**).
14. *Quiz*: recalling knowledge in various categories such as history, geography, food, etc. (**memory**).
15. *Suitcase*: placing a new object in the correct position so that the suitcase closes without collisions with existing objects (**perception**).

The patients may use the platform at home either independently or together with a family member or a caregiver in case of severe cognitive impairment. The user interface design has been developed taking into account the characteristics of the elderly which call for simplicity, clarity, consistency and adaptability to the skills of each individual (Gerling et al., 2012). Fig. 1 shows sample screens regarding two of the games.

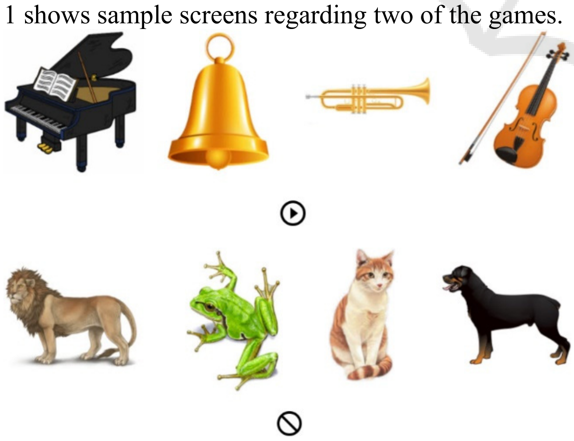

Figure 1: Snapshots from *FindTheSound* (top) and *Outsider* (bottom) games.

Fig. 2 shows, as another example, the user interface for the *ChronologicalOrder* game. The user has to drag picture pieces to the correct time space to create a meaningful story. The game has three difficulty levels, i.e. easy, medium and advanced levels which are associated to a story with 3, 4 and 6 picture pieces. The time sequence of a 3-pieces story is defined from the top of the screen downwards. The time sequence of 4-pieces or 6-pieces story is defined from left to right and top to bottom.

Figure 2: An instance of the *ChronologicalOrder* game.

Figure 3: Example of a 3D scene used in the games.

Some games are planned to use 3D representations of physical objects and scenes (Fig. 3). The human brain is used to managing 3D images, so it is more natural to interact with 3D objects than flat images or text. So using a more natural representation of objects seems a better idea and more efficient in terms of rehabilitation. In addition, 3D models give the patient the ability to interact more fully with them, but also allow the rehabilitation specialist to control every aspect of their appearance.

3.3 Ontologies

Ontologies are used in Knowledge Engineering for modelling a domain in a structured representation form containing its clear definition (Gomez-Perez et al., 2006). To make this modeling correctly, all entities, properties, restrictions or other assumptions that exist in the domain of interest are specified. This specification must be modeled in a language comprehendible by both humans and machines (Baader et al., 2004).

There are many formal languages that can be used to define and construct ontologies, with the aim of codifying the targeted knowledge in a simple and formal way. However, the most popular approach involves the use of the RDF (Resource Description Framework) standard and the OWL (Ontology Web Language) language (Welty et al., 2004). An ontology can, therefore, be formally described in OWL by using classes, objects, and properties as key attributes. These elements are used to describe concepts, instances or members of a class, as well as relationships between objects of two different classes (*object properties*), and relationships that link objects to data types (*data properties*). OWL supports also the expression of equivalences or assumptions in the form of axioms that combine entities and relationships. In this work, the OWL 2 DL (Description Logic) profile was used to specify the ontology models.

On the other hand, the existence of rules helps to combine the knowledge of an ontology with corresponding dynamic knowledge contained in these Rules. a Rule-based System Usually Contains a Set of "if-then" Rules That Indicate the next Action to Be Made, Depending on the Current Situation, and Also a Rule Mechanism to Implement Them. Thus, using a Set of Rules Makes It Possible to Express the Behavior of Individuals within a Domain, Thereby Providing New Insights for These Individuals and, Consequently, Personalized Services (Skillen Et Al., 2014).

in This Context, the SPARQL (SPARQL Protocol and RDF Query Language) Language Was Used to Query the Knowledge Base of the Ontology and to Describe Rules That Encode Expressions over the User Profile Instances. despite Being a Query Language, SPARQL Provides Extensive Power to Guide the Provision of Personalized Services by filtering Persons with Certain Characteristics (Applying the FILTER NOT EXISTS Construct), Asserting New Facts (Applying the CONSTRUCT Expression), Updating Data in the Ontology (Applying the UPDATE Expression), Etc. Therefore, Personalized Game Activities Can Be Defined via SPARQL Rules According to User Conditions and Preferences.

Protégé (V. 5.5.0) Ontology Editor Was Used to Create the Ontologies. Protégé Is a Software Tool That Enables the Creation of an OWL Ontology and Supports the Capabilities of the OWL Language. Protégé Supports the Definition of a Hierarchy of *Entities-Classes* as Well as the Ability to Create *Relationships-Restrictions* via a Handy Graphical User Interface Instead of Directly using the OWL Language. It Also Integrates Various Reasoners to Control the Consistency of the Ontology as Well as for Inference Purposes. in This Work the Pellet Reasoner, an Open Source Java OWL-DL Reasoner, Was Chosen. Finally, It Provides Useful Ontology Information Such as the Set of Axioms, I.E. the Self-Proven Values, Which Exist in the Ontology.

for a Selected Entity, Protégé Lists the Relationships with the following Syntax Which Is Adopted in the next Sections:

<Relationhip-Name> <Cardinality> <Cardinality Value (Optional)> <Range of Relationship>

Where *<Cardinality>* May Be One of the following Keywords: *Min*, *Max*, *Exactly*, *Only*.

the following Notation Is Also Used for Expressing Relationships: *OP* Denotes *Objectproperty* Relationships, *DP* Denotes *Dataproperty* Relationships and *Obj* Denotes All Entities That Are Objects.

for Example, the following Restriction: *Hasmathoperation (OP) Max 5 Mathoperator (Obj)*, Is Interpreted as the *Hasmathoperation* Relationship Is an *Objectproperty* with *Max* Cardinality the Number 5 of the *Mathoperator* Entity-Object.

3.3.1 User Profile

In COGNIPLAT platform, there is a need for describing, in addition to the static user traits, dynamic aspects that relate to specific game activities in which the user engages. The *User Profile* (*UP*) uses temporary sub-profiles of a user profile in order to encode game activity related user preferences.

In UP ontology, a user's *Profile* has a permanent sub-profile which contains static information about the user and a set of temporary sub-profiles. The *PermanentSubProfile* contains *GeneralInformation* (e.g. name, age, gender, height and weight), *Likes*, *Dislikes*, *Disabilities*, *ContactInformation*, *SocialInformation* (e.g. friend and family_member), *Possessions* (e.g. object, and living_thing), and *HealthInformation* (e.g. medication, diseases, allergies, etc.). Each *TemporarySubProfile* contains *Preferences* (e.g. privacy_preference, interaction_preference, environmental_condition_preference, etc.) which are associated with the *GameActivity* that a *User* carries out. Moreover, each temporary sub-profile depends on the *UserContext* which contains the *Location* of the user, the *Time* in which the activity is carried out, the *State* of the user, which means whether the user is "alone" or "with-friends", and the user's *Mood*. Fig. 4 depicts the relations between *Person*, *Profile*, *TemporarySubProfile* and *PermanentSubprofile* and the properties of each sub-profile. In particular, a Person has exactly one permanent sub-profile and several temporary sub-profiles.

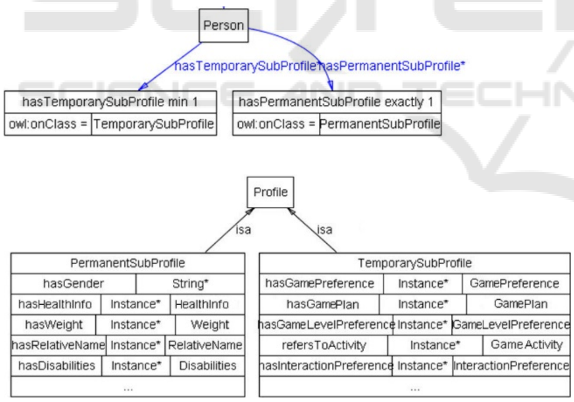

Figure 4: Visualisation of a part of the UP Ontology.

Leveraging on UP data the game platform can select favourably game resources that are aligned to the stored preferences of each patient (e.g. favourite sports, food, hobbies, animals, music, etc.). This personalization of the exercises can increase user engagement and platform acceptability. Similarly, the declared educational level can adjust the exercise parameters (e.g. completion time, performance threshold to change the difficulty level) and exercise plans (e.g., minimize the use of certain games) according to the patient capabilities.

3.3.2 Game Rules

A basic goal of this ontology is to represent also the knowledge of the game rules and their constituent resources so that game instances can be automatically created by an application server. Also, the ontology should be easily extensible in order to specify new games following a specific pattern. The ontology also enables the correlation between resources, resulting in a greater variety of entities that can be associated to the rules of the game. The ability to associate entities with one another can lead to new games, such as finding the sound that can characterize a word.

After analyzing the logic of the fifteen MCI rehab games some basic properties have been identified:

- There are different difficulty levels for a game;
- There is a time limit to play a game;
- There is a maximum number of repetitions for a game;
- After a number of correct answers the difficulty level of a game increases;
- A game is associated with resources that can be words, operators, blocks, puzzle pieces, questions, images, videos and sounds.

Therefore, the two main entities of the Games ontology are:

1. *Game*, this is the basic entity associated with the basic properties of a game such as the difficulty level. Every game that is modeled must have this entity as a base class.

2. *Resource,* this is the base class entity of each resource that is modeled. The only common feature among different resources is a unique id.

These entities are independent of each other, i.e. a *Game* entity does not intersect with a *Resource* entity and consequently an individual *Game* cannot be a *Resource*.

The *Game* entity has the following data properties:

1. *maxCompletionTime (DP) value n*, specifying the time allowed to complete the exercise which can vary depending on the difficulty level of the game. The value is an integer corresponding to a time measured in seconds.

2. *completedDate (DP) value xsd: string*, specifying the end date of the current game.

3. *hasDifficulty (DP) value {"EASY", "MEDIUM", "HARD"}*, specifying the difficulty of the game.

4. *hasGameId (DP) value xsd: string*, specifying a unique identifier of the individual game. The syntax of such an identifier is: *<game name>_<difficulty level>_<player name>_<round number>*.

5. *hasLevel (DP) value xsd: string*, specifying the current level of the game.

6. *hasPlayer (DP) value xsd: string*, specifying the player's alias.

7. *isCompletedIn (DP) value xsd: positiveInteger*, specifying the time in secs for actually completing the current game.

For each developed game an entity is defined in the ontology. As an example, the entity in Fig. 5 describes the game of associating images to sounds (*FindTheSound*). The number of images displayed in this game increases with respect to the difficulty level. The restrictions (object properties) defined in the ontology for the *FindTheSound* Game entity are as follows:

1. *hasImage (OP) exactly n ImageSound (obj)*, specifying the number of images to be used as options with the associated sound.

2. *hasSound (OP) exactly 1 Sound (obj)*, specifying the sound the user hears with the associated image.

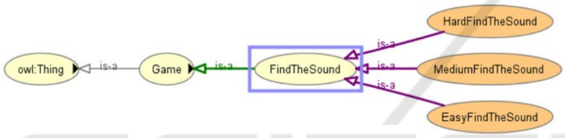

Figure 5: *FindTheSound* Game entity in the ontology.

Similarly, for each resource used in the games an entity is defined in the ontology. Fig. 6 describes, as an example, the image class. Each image is associated via the OP relationships *hasTitle* and *hasSubject* with a couple of *Word* entities. In this way, an image can be categorized based on the *hasSubject* relationship and consequently rules can be defined that require images from a specific category. Also, in this manner, games that focus on a *Word* entity can contain rules with corresponding images, such as finding opposite emotions. The *Image* entity is analysed into two subcategories:

1. *OrderedImage*, describing one image and its association with another image via the OP relationship *hasPreviousImage*. It was observed in the developed games that each image may have at most one precursor, which actually characterizes the property as *Functional* (i.e. any entity that belongs to the domain of this relationship can be associated at most with one entity, which belongs to the range of the relationship).

2. *ImageSound*, describing the association of an image with a sound via the OP relationship *hasAssociatedSound*.

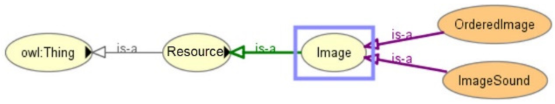

Figure 6: Image Resource entity in the ontology.

The ontology contains also relationships that associate games with resources and resources with other resources. A subset of these relationships is provided next in the following format: *relationship(D: Domain, R: Range)*:

hasAntonym(D:Word, R:Word)
hasSynonym (D:Word, R:Word)
hasAssociatedSound(D:Image, R:Sound)
hasAssociatedImage(D:Sound, R:Image)
hasBlock(D:BlockSet or Calculation or Labyrinth or HidingBlocks or LogicalOrder, R:Block)
hasBlockSet(D:LogicalOrder, R:BlockSet)
hasCategory(D:Question, R:Word)
hasChoice(D:Question, R:Word)
hasConnectingPiece(D:Piece, R:Piece)
hasOperator(D:Calculation, R: OperatorBlock)
hasObservation(D:Observation, R:ObservationObj)
hasPiece(D:Puzzle, R:Piece)
hasPreviousImage(D:OrderedImage, R:OrderedImage)
hasSubject(D:Image or Sound, R:Word)
hasTitle(D:Image or Sound, R:Word)

The Games ontology developed currently contains 103 entities with 36 OP relationships and 46 DP relationships. Fig. 7 shows the reported metrics of the developed ontology. The complete ontology is available in the Github repository (https://github.com/Binarios/MciOntology).

Ontology metrics:

Metrics	
Axiom	742
Logical axiom count	560
Declaration axioms count	182
Class count	103
Object property count	36
Data property count	46
Individual count	0
Annotation Property count	0
Class axioms	
SubClassOf	171
EquivalentClasses	69
DisjointClasses	25
GCI count	0
Hidden GCI Count	55
Object property axioms	
SubObjectPropertyOf	35
EquivalentObjectProperties	0
InverseObjectProperties	1
DisjointObjectProperties	1
FunctionalObjectProperty	11
InverseFunctionalObjectProperty	0
TransitiveObjectProperty	0
SymmetricObjectProperty	4
AsymmetricObjectProperty	0
ReflexiveObjectProperty	0
IrrefexiveObjectProperty	7
ObjectPropertyDomain	35
ObjectPropertyRange	35
SubPropertyChainOf	0

Figure 7: MCI Rehab Games Ontology metrics.

3.4 Game Generator

In this section the back end of the COGNIPLAT platform which generates game instances for MCI rehab client applications is described. The ontology is accessed by a server, which reads the stored rules and then automatically generates game instances that are appropriate for the specific clients. One of the difficulties was the discovery of the available games by a MCI rehab client application as the latter has a different life cycle than the ontology. This discovery is achieved as all the games are available under the provision of a server. This makes it possible to communicate with the client application from any device to access the available games at any time, without the intervention of a third party, such as medical personnel. The interaction sequence to discover the games is shown graphically in Fig. 8.

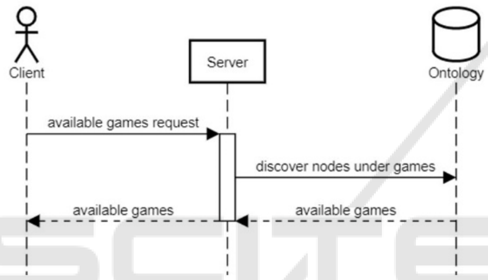

Figure 8: Interaction for the discovery of available games.

Fig. 9 illustrates the system architecture. The COGNIPLAT platform consists of one Tomcat server for running game services and a second Tomcat-based server hosting: a) the ontology model, which must be loaded at startup into the memory of the application server; b) resource files, such as images and sounds, which are needed by the games; and c) the knowledge base with the game rules. For the latter, the Apache Jena Fuseki server is employed. This server supports the SPARQL Protocol and serves as an ontology provider hosting the knowledge base. It enables SPARQL queries to be executed on the knowledge base, thereby enabling immediate access to the ontology. The accompanied Apache Jena, provides three different APIs. The RDF API supports the creation and reading of RDF triplets. Another API deals with Apache Fuseki functionality as well as the dynamic management of the knowledge base. Finally, the OWL API offers tools and methods to create and access rules in the ontology. The OWL API also provides access to the Pellet reasoner enabling flexibility to the game application by exploiting inferred knowledge on demand.

The COGNIPLAT platform embraces the *microservices architectural style* to deploy game applications as lightweight services that can be independently developed, tested, deployed, operated, scaled, and upgraded (Newman, 2015). Typically, microservices communicate with each other via HTTP, but in this work the *dependency injection* (DI) design pattern was used in an attempt to mimic microservices. This design pattern increases the decoupling between classes of an application thus achieving greater isolation between them, easier testing of their functionality as well as support for the microservices architecture (Prasanna, 2009).

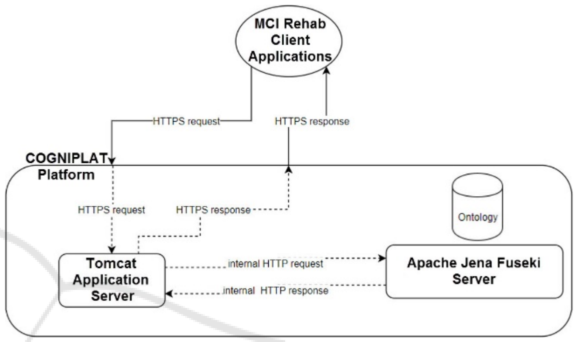

Figure 9: COGNIPLAT platform architecture.

Therefore, in COGNIPLAT platform each game is implemented as a separate service (Fig. 10). Each service contains the logic that describes which resources will be used for the game as well as whether an object needs to be created, and what its value will be according to the constraints specified in the ontology. Also every service is accessible remotely through an API gateway.

Besides game services there is the ontology service that is responsible for reading the rules of each game and communicating with the knowledge base to create the requested resources. The ontology service hides from the game services the ontology structure and storage. In this way it is possible to change the ontology technology without disturbing the rest of the system.

During the platform bootstrap, the owl schema is downloaded from the Apache Fuseki server and is loaded into the memory. Following the ontology model load, each game-microservice has access to the rules of the schema and can generate an instance of the game which is then saved in the common knowledge base. In this way each microservice has access to the same rules and to the same knowledge base.

The client application (e.g. a health application, an agent, a healthcare expert through a front-end tool) can only access the games services and not the ontology service. Because the services have their own API gateways for communicating with each other, it is necessary to create a master API gateway that only exports the gaming services gateways (Fig. 10).

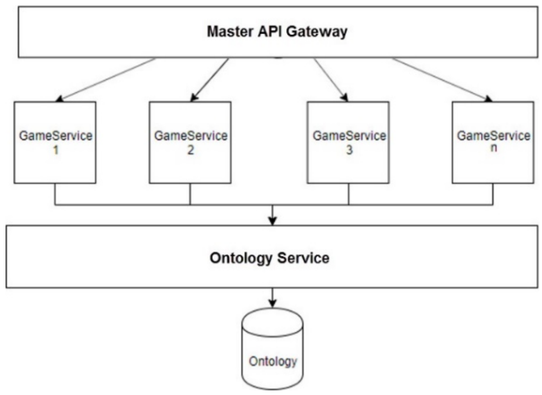

Figure 10: COGNIPLAT platform as a service architecture.

All COGNILAT platform services accept requests in the JSON (JavaScript Object Notation) format and respond to the same formatting. Table 1 lists the supported endpoints of COGNILAT platform services where *{resource}* denotes one of the available games.

Table 1: Endpoints of COGNILAT platform services.

HTTP Verb	Resource URL	Response
GET	/mci/{resource}	All available game instances
POST	/mci/{resource}	A created game instance
GET	/mci/{resource} /{id}	A specific game instance
PUT	/mci/{resource} /{id}	Resolution of a specific game instance

Fig. 11 and Fig. 12 show as an example the use of the HTTP POST message to request the creation of a *FindTheSound* game instance and the corresponding response message payload.

```
POST /mci/FindTheSound HTTP/1.1
Host: localhost:8443
Content-Type: application/json
X-INFO-PLAYER: Postman
cache-control: no-cache
{
    "difficulty": "easy"
}
```

Figure 11: Request message for creating an instance of the *FindTheSound* game.


```
{ "payload": {
  "images": [ {
    "iId": "Image_9c90b4a254c142edb29c9bfca7287a1c",
    "iPath": "\\WB\\mci\\resources\\images\\cat.jpg"
  },{
    "iId": "Image_16ba6b21974f411f9b3931b0cafa360c",
    "iPath": "\\WB\\mci\\resources\\images\\dog.jpg"
  },{
    "iId": "Image_6442d418cd584e969a644c87671fdea2",
    "iPath": "\\WB\\mci\\resources\\images\\donkey.jpg"
  } ],
  "sId": "Sound_2ec5c2314c2b4748a8a7fb40c8e7fe83",
 "sPath":"\\WB\\mci\\resources\\sounds\\donkey.mp3",
  "game": {
    "id": "FindTheSound_EASY_Postman_1",
    "difficulty": "EASY",
    "playerName": "Postman",
    "level": 1,
    "maxCompletionTime": 180
  },
  "resolved": false
} }
```


Figure 12: Response message for the *FindTheSound* game.

Fig. 13 shows as an example the request message for resolving the choice of the user Postman for a specific *FindTheSound* game instance. Fig. 14 gives the SPARQL query for finding the triplet that associates the image selected by the user with the sound via the *hasAssociatedSound* relationship. The game service would then be able to check the correctness of the user choice.

```
PUT /mci/FindTheSound/FindTheSound_EASY_Postman_1
HTTP/1.1
{
  "completionTime": 18,
  "resolution" : {
  "sId": "Sound_2ec5c2314c2b4748a8a7fb40c8e7fe83",
  "iId": "Image_6442d418cd584e969a644c87671fdea2"
  }
}
```

Figure 13: Request message for resolving user’s choice.

```
PREFIX mci: <http://localhost:3030/mci/ontology/mci#>
SELECT ?subject ?predicate ?object
WHERE {
 ?subject <mci:hasId>
"Image_6442d418cd584e969a644c87671fdea2";
      <mci:hasAssociatedSound> ?object.
}
```

Figure 14: SPARQL query to find the association between resources via the *hasAssociatedSound* relationship.

4 EVALUATION – DISCUSSION

An experimental evaluation was conducted in terms of technology acceptance of the game platform involving 15 elderly volunteers by using both quantitative and qualitative data. All participants were healthy and over 65 years of age (9 male and 6 female, mean 68.7±3.8 years). The evaluation process comprised the following steps that performed by each participant: i) read and sign the consent form; ii) complete the demographic questionnaire; iii) complete the Montreal Cognitive Assessment (MoCA) test (Nasreddine et al., 2005); iv) make thorough use of the game platform by mimicking a rehabilitation session; v) complete the SUS (System Usability Scale) questionnaire (Brooke, 1996); vi) attend a brief semi-structured interview session.

All participants had a good cognitive functioning as assessed by the MoCA test (score above 26) except from two cases with a score between 18 and 26 which is considered average. The education level varied as primary (13%), secondary (67%) and higher (20%).

By employing the SUS questionnaire the perceived usability of the game platform can be assessed. The questionnaire includes ten statements (Fig. 15) with five scale responses from 1 (strongly disagree) to 5 (strongly agree).

S1. I think that I would like to use this system frequently.
S2. I found the system unnecessarily complex.
S3. I thought the system was easy to use.
S4. I think that I would need the support of a technical person to be able to use this system.
S5. I found the various functions in this system were well integrated.
S6. I thought there was too much inconsistency in this system.
S7. I would imagine that most people would learn to use this system very quickly.
S8. I found the system very cumbersome to use.
S9. I felt very confident using the system.
S10. I needed to learn a lot of things before I could get going with this system.

Figure 15: SUS questionnaire statements.

The participant's grades for each item were processed so that the original scores of 0-40 are converted to 0-100. The average SUS score was 80 out of 100 (Median=85, Fig. 16), suggesting a good user acceptance (Bangor et al., 2008). Fig. 17 summarizes the SUS questionnaire results indicating for each statement the distribution of the 5-scale ratings. The responses in S2, S6, S8 and partly in S10 indicate that the participants have a firm judgement that the use of the game platform is simple, consistent and handy while the learnability effort is low. On the other hand, a more attentive response is provided in terms of S4 and S9 as their median ratings are stronger than the extreme and more definite ratings. These statements actually express the capacity of the participants to handle the system on their own without the support of an expert. The interpretation of the above variation is attributed to the less familiarity with technology for some participants as well as to the general fear for the technology that the elderly often feel.

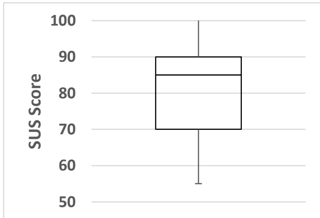

Figure 16: Perceived usability as conveyed by SUS score.

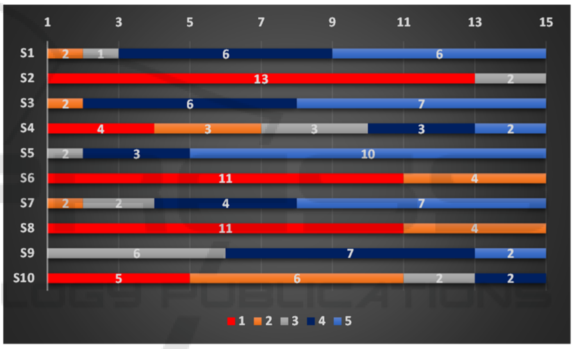

Figure 17: SUS questionnaire ratings.

In addition, a brief interview with each one participant was conducted to acquire qualitative data. The analysis of this feedback affirms the previous results indicating that participants believe that the system complexity is low, the game platform is easy to understand on its operations and doesn't require much effort to use. Particularly noteworthy was the feedback from several participants who believe that their memory will positively improve over time via practicing with the application. On the other hand, 20% of the participants (3/15) responded that they would definitely need support to complete some games. The majority of the participants also expressed a preference towards games that use image and sound resources than text-based exercises, which opens possibilities for improvements in the games.

The cognitive level, the familiarity with the technology and the educational level are factors that affect the acceptability of any computerized system. The design of the games and their user interface followed a user-centered design approach from the beginning of the development process targeting a high usability and efficiency. According to this pilot evaluation that goal was achieved to a very good degree.

An evaluation of the game platform regarding its MCI rehabilitation objective is underway. The methodology includes a control group and an intervention group applying a randomized controlled trial. For all users, measurements of cognitive functions are recorded before using the COGNIPLAT platform, while after the intervention the same measurements will be recorded only for the intervention team. The intervention team will use the COGNIPLAT platform 1-2 times a week until each participant completes 24 sessions of use. The Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) scales will be used for assessing cognitive improvements.

The following performance data are collected by the COGNIPLAT platform for each user and for each game: correct answers, wrong answers, quits (i.e. the EXIT button was selected before the game round was completed), the total time the game was played in minutes, how many different days the game was played, the points earned in accordance with the point system and the overall accuracy percentage. The data collection process is in compliance with the requirements of the General Data Protection Regulation and patient information is anonymized by removing their identifiable and personal data.

The performance data is analysed by the platform in order to adapt the game difficulty to the user improvement. For example, if the performance of the user during a specified time-frame (e.g. 2 weeks) or over a number of successive sessions, is higher than a specified threshold (e.g. 75%), the game level will be increased automatically. Moreover, the stored data can be processed by machine learning algorithms to determine more effective exercise plans to improve the required cognitive skills, whereas the discovery of patterns can assist the classification of patients to diagnostic levels. This functionality is expected that will increase more the engagement of the users and their willingness for continuous practicing with the platform.

5 CONCLUSIONS

The field of rehabilitation combined with technological innovation (wearables, serious games, robotic systems) opens up new avenues for telemedicine and home care research. It is now possible to transfer treatment from care centers to home and to use computers for rehabilitation. Statistics show that most patients prefer the use of new technologies for their recovery, and the results of these methods are better than the corresponding traditional ones. In addition, the per capita cost of rehabilitation of these patients is significantly reduced, and the quality of services provided is significantly increased. Consequently, older patients will be able to receive services for a long time without a significant burden on the health system.

As for the use of ontologies in MCI health care applications, their benefits are obvious. It is possible to personalize intervention practice exercises and also to significantly differentiate between game instances. All of these play a crucial role in the end result because they allow the patient to engage in the exercises for prolonged time periods without getting tired. More persistence in exercises yields better recovery results.

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